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THE ORE DEPOSITS AND PROCESSING FACILITIES OF THE USSR HEAVY NONFERROUS METAL INDUSTRY

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DEPOSITS OF THE LEAD AND ZINC INDUSTRY

The distribution of the prospected polymetallic deposits in the USSR is as follows: the Kazakh SSR has 75-80 percent of the lead reserves and 74 percent of the zinc; the Uzbek, Kirgiz, and Tadzhik SSRs have 9-10 percent of the lead reserves and 4 percent of the zinc; the North Caucasus has 6-7 percent of the lead reserves and 7 percent of the zinc; Primorskiy Kray has 6-7 percent of the lead reserves and 9 percent of the zinc.

The USSR lead and zinc polymetallic deposits may be divided into the following groups, according to their composition:

1. Deposits, poor in dispersed elements, in which silver is the only precious metal present in commercial quantities; of the other metals present, the only one of commercial value is cadmium (Achisay).

2. Deposits containing high tin concentrations, silver, indium, thorium, and molybdenum; the ores frequently contain copper (Primorskiy Kray).

3. Deposits in which copper, cadmium, selenium, tellurium, silver, and gold (Nikolayevskoye, Belousovka in the Altay, Yuzhno-Darbazinskoye, and other deposits) are present.

4. Deposits containing cadmium, antimony, bismuth, copper, silver, and gold (Sokol'noye, Zyryanovsk, Ridder, and Sadon).

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By origin, all the polymetallic deposits belong to the hydrothermal type of formation.

The polymetallic deposits of the USSR can be divided into eight geographic regions:

1. The region of Sikhote-Alin' (Primorskiy, Far East) including the large Tetyukhe deposit.

2. Nerchinsk region (Eastern Transbaykal) including the large Kadainskoye deposit.

3. Salair region (Western Siberia) including the deposit of the same name.

4. Altay (Kazakhstan) including the large Sokol'noye and Zyryanovsk deposits.

5. Dzhungarskiy Ala-Tau including the Tekeli deposit.

6. Region of the Kara-Tau mountains (Southern Kazakhstan) including the large Mirgalimsay deposits.

7. Region of the Kara-Mazar mountains (Uzbekistan) including a number of polymetallic deposits.

8. North Caucasus region including the Sadon and Buronskoye deposits.

In addition to these, other deposits of polymetallic ores are found in Yakutiya, the Transcaucasus, on the island of Vaygach, and in other regions.

Deposits of the Far East

The Far Eastern polymetallic ore deposits are located on the shore of the Sea of Japan on the eastern slope of the Sikhote-Alin' Range. The largest prospected deposits now being worked are those at Tetyukhe.

The form and stratification of the ores are extremely varied: ore lentils on the contacts of limestone and quartz porphyries, stratified lentils and veins on seams of limestone and tuff with clay shales, stratified cross veins in clay shale, and zones of phenocrysts and strata of fine-grained variable streaks in quartzites and chert, have all been observed.

The sulfide ores consist of galenite, zinc blende, chalcopyrite, pyrrhotine, pyrite, marcasite, arsenopyrite, small quantities of tetrahedrite, tennantite, and sometimes cassiterite. Vein minerals are manganosiderite, calcite, garnet, quartz, barite, epidote, etc.

The composition of the ores changes with depth. In the upper strata of the hydrothermal zone, the quantity of heavy silicates, chalcopyrite, and pyrrhotine decreases and the quantity of quartz and calcite increases. Bismuth has been observed in some parts of the deposit. Cadmium appears in spots. The zone of oxidation in some deposits is lacking. Tube-shaped beds of oxidized ores form separate pockets which lie to the side of the main pyrite beds. The oxidized ores consist of smithsonite, hydrozincite, willemite, cerussite, malachite, azurite, pyrolusite, and limonite.

Among the larger deposits of the Sikhote-Alin' mining region is Verkhniy Rudnik, the largest prospected polymetallic deposit, located on the high ridge of the left bank of the Borisovskiy Gorge and the Tetyukhe River. The sulfide ores consist of zinc blende, galena, chalcopyrite, pyrrhotine, pyrite, arsenopyrite,

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tetrahedrite, and chalcosine. The following vein minerals are found: hedenbergite, thermolite, manganosiderite, calcite, quartz, and sometimes barite, garnet, and ilvaite.

There are also a number of other deposits in Primorskiy Kray which have not yet been sufficiently prospected.

All ore mined here goes to the Tetyukhe Concentration Plant. As a result of selective flotation, two types of concentrates are obtained, namely, lead and zinc. The lead concentrates are treated on the spot at the lead-smelting plant. The zinc concentrates are sent to zinc plants.

Deposits in Eastern Transbaykal

The majority of deposits in the Eastern Transbaykal (Nerchinsk region) are located in the area between the Shilka and Argun' rivers and the Transbaykal Railroad. Almost all of these deposits are associated with limestone or dolomite. The ores are divided into oxidized and primary [classes]. The zone of cementation is poorly developed.

The Nerchinsk deposits are characterized by the presence of a large number of varied metals including lead, zinc, copper, silver, arsenic, gold, tin, antimony, tungsten, and several other elements. Thus, the mineralogical composition of these ores is exceptionally complex. The minerals found in the oxidized ores are: limonite, psilomelane, cerussite, smithsonite, mimetesite, scorodite; and, among nonmetallic ores, various carbonates and quartz. The primary ores consist of pyrite, arsenopyrite, sphalerite, galenite, boulangerite, and pyrrhotine (in some cases marcasite, cassiterite, and others are found); the nonmetallic ores include calcite, dolomite, manganosiderite, quartz, sericite, and tourmaline. The ores are of the disseminated type; compact ores are seldom found. The Nerchinsk region is potentially very rich in reserves of lead, zinc, silver, arsenic, and other metals.

Deposits in Western Siberia

The Salair deposits of polymetallic ores are located on the northeastern slope of the Salair range. The ore beds are located on the long axis of an ellipse. In form, the greater number of the Salair ore deposits are irregular lentil-forming bodies. Beds in the zone of oxidation contain ocherous barite with a considerable silver and gold content.

The composition of the rock surrounding the Salair deposits is quite uniform. In the upper levels the ores are quartz-barytic, in some places purely barytic. In the lower levels they are barytic-quartz and carbonate-barytic-quartz.

Sulfides are distributed in a state of very minute dissemination, uniformly throughout the entire mass of ore and are seldom concentrated in the form of bands.

Among the mineral ores in the Salair deposit the following have been determined: sphalerite, pyrite, galenite, tetrahedrite, chalcopyrite, tennantite, covellite, chalcosine, argentite, cerussite, native silver and gold, and barite. Quartz represents rock containing no metal.

The ores from the Salair Mine are refined at the Salair Concentration Plant. Through a process of selective flotation, three types of concentrates are obtained: zinc, lead, and barite.

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Altay Deposits

The Altay polymetallic ore deposits are located on the southwestern spurs and foothills of the Altay Mountains. They are the chief ore base for lead and zinc production in the USSR.

Besides lead and zinc, the Altay ores contain copper, cadmium, antimony, gold, and silver. The polymetallic ore deposits occupy a unique position in their content of precious metals. The extraordinary quantity of gold and silver found in the upper oxidized levels of these deposits was the reason for their being worked more than 100 years ago. During the 1880's, the working of the Altay mines began to decline because the reserves of oxidized ores rich in silver were exhausted and because of difficulties involved in working the sulfide ores at deeper levels. In 1892, when the price of silver fell drastically, working of the Altay mines almost came to a stop.

Now, as a result of the development of techniques for refining sulfide and lean ores, the Altay deposits are among the most important in the USSR, because of their prospected and estimated reserves.

The ore beds are found here in limestone, tuff, schists, and porphyries. The morphology of the Altay deposits is quite varied, although a form of complex beds predominates. Usually beds of compact pyritic ores are accompanied by more or less significant zones of phenocrysts. The primary ores of the polymetallic deposits include pyrite, sphalerite, galenite, chalcopyrite, and tetrahedrite. Arsenopyrite and pyrrhotine are less frequently found. The gold in these ores is in a native state. Vein minerals are quartz, barite and, in small quantities, carbonates, sericite, and chlorite.

In many of these deposits there has been observed a zonal change, according to depth, in the character of the ore; the quantity of sphalerite and pyrite increases and barite is replaced by quartz. The oxide ores are richer in gold and silver and have a lesser zinc content.

In the distribution of the Altay deposits, it is possible to distinguish four fields of mineral concentration:

1. The Leninogorsk field with the large Leninogorsk and Sokol'noye deposits and the smaller deposits of Kryukovskoye, Il'inskoye, Uspenskoye, and Filippovskoye.

2. The Zyryanovsk field with the large Zyryanovsk deposit and a number of smaller deposits such as those at Zavodinsk, Bukhtarminskoye, etc.

3. The Irtysh field with the Belousovka, Berezovka, Nikolayevskoye, Talovskoye and other deposits.

4. The Zmeinogorsk field with the large Zmeinogorsk and Petrovskoye deposits and smaller Semenovskoye, Cherepanovskoye deposits, etc.

Of these four, the Leninogorsk field is the most important in its prospected and potential reserves of ores.

Dzhungarskiy Ala-Tau Deposits

The Tekeli deposit is located in the region of the western slopes of the Dzhungarskiy Ala-Tau Mountains, 100 kilometers from the Taldy-Kurgan Station on the Turksib Railroad. More than 20 polymetallic deposits have been discovered in the Tekeli area. They are localized near the contact of a granite intrusion and are adapted to an ore level which consists of clayey, carbonaceous, and limestone shales.

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The basic mineral components are pyrite, sphalerite, galenite, quartz, calcite, and dolomite. An almost complete absence of copper is characteristic of the Tekeli ore area. The ores are argentous, with the silver occurring in the form of a solid solution with galenite. Rare and dispersed elements are observed in the ore in insignificant quantities.

Zones of oxidized and sulfide ores are differentiated. In the oxidized zone the ratio of lead to zinc is exactly one.

In the sulfide zone three types of ores are differentiated: compact, with a one to four ratio of lead and zinc; disseminated, with ores about three times leaner than the compact ores and with a one to two ratio of lead and zinc; and pyritic ores, with a one to three ratio of lead to zinc.

The Tekeli ores are relatively easily subjected to flotation. In metal reserves, the Tekeli deposit has extremely good prospects.

Kara-Tau Deposits

The mountains of Kara-Tau in southern Kazakhstan occupy an important place among the polymetallic ore regions of the USSR.

The ore minerals are: galenite, sphalerite, pyrite, and infrequently chalcopyrite and arsenopyrite. The dead rock contains calcite, dolomite, siderite, and now and then, quartz and barite. The ores of the Kara-Tau region are slightly argentous.

Near the surface the ore deposits are almost always oxidized, with the zone of oxidation frequently reaching a great depth. The zinc sometimes appears to have been leached and redeposited outside of the lead ores, forming secondary segregations of almost pure oxidized zinc ores with a small lead content.

The oxidized ores are strongly ferrous. They are porous, yellow or reddish-brown in color, and consist of echerous, sometimes clayey, iron ores containing oxidized lead and zinc minerals.

In the oxidized zone, the lead minerals are represented chiefly by cerussite and, in insignificant quantities, by anglesite and plumbojarosite. Zinc is present in the form of smithsonite, hydrozincite, and mangenmite (carbonate of iron and zinc). Zinc is also present in the form of a peculiar, soft, stearin-like silicate of aluminum and zinc, in which the two latter elements appear in different ratios, isomorphically replacing one another.

The great majority of the lead-zinc deposits of Kara-Tau are located in Central Kara-Tau (Turlan, Kantagi, Mirgalim-say, Kara-say, and others). The isolated deposits of Baydzhansay and Suleymansay are located in southern Kara-Tau. The largest prospected deposits are Achi-say and Mirgalim-say.

Karamazar Region (Uzbekistan)

In this region, the deposits of polymetallic ores are located on the southern slopes of the Karamazar Mountains.

The ore deposits of Karamazar can be divided into two geological groups: deposits found in igneous rock, and deposits associated with limestone.

The deposits found in igneous rock belong to the hydrothermal type and consist of sulfide polymetallic ores of complex composition. The principal metals found in them are lead, silver, zinc, iron, and, to a lesser extent, copper. Some of the ores also contain arsenic, antimony, cadmium, gold, and, occasionally, tungsten and molybdenum. The ore minerals are scattered throughout the mass of veins.

The segregations of industrial value are in the form of separate lentils or columns of irregular shape. The upper zones of the deposit contain oxidized ores. Among the various deposits of this group, the following should be mentioned: Kan-i-Minsur, Tary-Ekan, and others.

Deposits of the second group, those associated with limestone, consist of rich polymetallic ores, containing mainly sulfides of lead and zinc and, less frequently, sulfides of arsenic, iron, and copper. Deposits of this group are at Kan-say, Takeli, Altyn-Topkan, and Yuzhnaya Darbaza.

Deposits in the Northern Caucasus

In the northern Caucasus there are several regions in which the deposits are more or less closely grouped, including the regions of Sadon (North Osetian ASSR) Adygey, and Samurskiy (Dagestan). The most important is the Sadon region in which are located the Sadon deposit, largest in the Caucasus, and the smaller Buronskoye, Zgidskoye, Kholstinskoye, and Arkhonskoye deposits.

The Sadon polymetallic ore deposit is located in the gorges of the Sadon River and its left tributary, the Khoddon. The deposit lies in granite of ancient age and is in the form of an irregular vein cut through by a number of faults. The vein appears to consist of separate lentils which, with few exceptions, are not of great length either horizontally or vertically.

The ore mined in the Sadon deposit is sent to the concentration plant in Mizur. Both lead and zinc concentrates are obtained by selective flotation.

DEPOSITS OF THE COPPER INDUSTRY

The distribution of copper ore deposits, according to the prospected copper reserves, is shown in the following table:

Distribution of Copper Ore Deposits

Region	Percent of Total
Urals and Bashkiriya	16.3
Kazakhstan	57.2
Uzbekistan	17.5
Others	9.0

The ores of the Urals belong to the chalcopyritic type. They lie in compact masses or are found in the form of phenocrysts in a series of dead rock. Deposits of chalcopyritic ores stretch in a belt throughout the entire Urals, from north to south.

The ores of Kazakhstan belong to the copper-porphyritic type (Kounrad, Boshchekul') or the copper-sandstone type (Dzhezkazgan).

More than half of the prospected reserves of copper in the Soviet Union are located in the Kazakh SSR. The reserves of copper are divided into separate categories of ores, as shown in the following table:

Distribution of Copper Reserves
According to Separate Ore Categories

Category	Percent of Total Reserves
Copper pyrites	15
Phenocrysts	56
Copper sandstones	21
Other copper ores	8

A large deposit of copper-porphyritic ore has been discovered at Almalyk in Uzbekistan. The Agarakskoye and Pirdoudan deposits of porphyritic copper-molybdenum ores are located in Armenia.

Ural Deposits

The pyrite deposits in the Urals are not uniform in composition. Some of them are formed almost entirely of pure pyrite; others contain, besides pyrite, different copper minerals which form natural chalcopyritic ores; a third type contain zinc blende in addition to copper minerals. Several varieties of chalcopyritic ores contain considerable quantities of zinc blende. The latter in some cases is present in even greater quantities than the copper minerals, causing a transition from copper-zinc ores to zinc-copper ores. The zinc blende is often found in close coalescence with other minerals, a fact which hampers the selective flotation of the ores. Some of the chalcopyritic ores contain lead glance and arsenous minerals. Almost all of the chalcopyritic ores are aurous.

The ore deposits of the Ural pyrite belt can be divided into two groups, based on the intensity of sulfide mineralization: uniform sulfide ores with a sulfide content of more than 80 percent, and scattered or impregnated sulfide ores with a sulfide content of 10-30 percent. Spatially, both groups are closely connected with one another.

Impregnated ores accompany uniform sulfide beds and have developed on the periphery of the beds. Mineralogically, the phenocrysts are similar to sulfides in composition. The impregnated minerals are: pyrite, chalcopyrite, sphalerite, and in the zone of the secondary concentration, covellite, and less frequently, chalcosine. The containing rocks are quartzsericitic shale, and less frequently, sheared albitophyres.

Geographically, seven basic regions of chalcopyritic ore concentration in the Urals can be observed. They are, from north to south: Bogomolovskiy, Nizhniy Tagil, Kalatinskiy, Revda, Karabash, Blyavinskiy, and Tanalyk-Baymak.

The Bogomolovskiy mining region encompasses the northern group of pyrite deposits on the eastern slope of the Ural range and includes the Kompaneyskiy, Novo-Levinskiy, Elektricheskiy, Spaso-Sernokolchedan, and Andreyevskiy mines. The deposits are found in sericitic shales jammed between albitophyres in the form of irregular bands stretching out meridionally and tapering off in the form of lentils. From above, the deposits are covered by iron hats beyond which there is a zone of friable pyritic material. The compact sulfide ores, which are located deeper, have a varying minerological and chemical composition. The following table shows the average content of sulfur in the compact sulfide ores:

Sulfur Content in Sulfide Ores

Ore	Sulfur Content
Chalcopyrite	40-48%
Low-copper (sulfur) pyrite	37-29%
Dense phenocrysts	25-35%

The Nizhniy Tagil mining region contains the deposits imeni "III Internatsionala" and the Ol'khovka deposit. The deposits imeni "III Internatsionala" with the mines of Mednyy, imeni "XV Godovshchiny Oktyabrya" and others, lie in quartz-sericitic shale. The pyrite is compact, striated, is partially of a type of phenocryst, and is made up of pyrite, sphalerite, and chalcopyrite. In the upper zones are found covellite and chalcosine. The deposits imeni "III Internatsionala" are characterized by a large content of zinc and precious metals. Arsenopyrite and galenite are found in the ores in especially large quantities. A high gold content is associated with the arsenopyrite, and a high silver content with galenite.

The Ol'khovka deposit is covered to a depth of 12 meters by an iron hat consisting principally of quartzitic limonite, containing precious metals. Below the iron hat lies zinc-copper pyrite formed of pyrite, sphalerite, and quartz, with very rare inclusions of chalcopyrite, but impregnated with veins of covellite. The approximate content of S, SiO_2, and Fe_2O_3 in these ores is shown in the following table:

Composition of the Ol'khovka Ores (%)

Ore	S	SiO_2	Fe_2O_3
Compact pyrites	35	19-23	--
Phenocrysts	21	51	28

In the Kalatinskiy mining region the deposits of pyrites are found in association with two belts of mineralized shale. The eastern belt includes the group of Kalatinskiye deposits of copper and sulfur pyrites; the western belt includes the Karpushinskoye and Levikha deposits, which are characterized by a high content of copper and zinc.

The Levikha deposits, although small in size, are noted for their large content of pyrites. Some of them are purely cuprous (Levikha 9, 11), others contain zinc (Levikha 1, 2, 3, 4). The Levikha 10 deposit is sulfur-pyritic. Among the ores in the copper-zinc lentils are pyrite, sphalerite, and chalcopyrite; and in the upper zones, covellite.

The Karpushinskoye deposit is a network of pyrite lentils, some separate and and others connected with each other by phenocrysts. The lentils are dissimilar in content. The majority of those lying near the footwall are sulfur-pyritic; those in the center, copper-zinc, and those of hanging wall, zinc copper. The ore-forming minerals include pyrite, chalcopyrite, sphalerite, bornite, tennantite, chalcosine, covellite, and galenite. The pyrites of complex composition have the characteristic striated texture. In the zinc-copper pyrites, the zinc content is two to three times the copper content.

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The Belorechenskoye deposit consists of series of lentils lying among sheared albitophyres and porphyrites. The basic ore minerals are pyrite, chalcopyrite, sphalerite, and, in the upper levels, covellite. Thin bands of amphibolic asbestos are found among the pyrites. The ratio of copper to zinc is exactly two.

The Kalatinskoye deposit is in the form of a branching lentil which includes pyrite, chalcopyrite, and often, sphalerite. The presence of magnetite is characteristic of the deposit. Covellite is present in the upper layers. The chalcopyrite contains up to 50 percent sulfur. The presence of arsenic and selenium in the ores is also discernible.

The Revda mining region is one of the largest prospected copper reserves in the Urals. The Degtyarka deposit is the thickest in this region. The ore-bearing zone consists of several veins, accompanied by phenocrysts. The average width of the lentil is 2-3 meters, while the maximum width is 6 meters. The ore contains pyrite, chalcopyrite, barite, and an insignificant admixture of sphalerite. The dead rock contains sericite and quartz; 70 percent of the copper is in the form of covellite. Secondary chalcosine is sometimes present in the form of an admixture. Copper minerals are scattered throughout the ore in the form of fine impregnations, 0.02-0.05 millimeter in size.

The Zyuzel'skoye and Gumeshevskoye deposits are also located in this region.

The Karabash mining region includes the group of deposits of chalcopyrites (Stalinskoye, Pervomayskoye, and others) which stretches in a chain along the Soymonovskaya Valley. These beds are in white quartz-sericitic shale. On the surface the beds appear as iron hats under which lies barite-quartz gold-bearing sand. Under the sand is a stratum of friable pyritic material. Compact massive pyrites start at a depth of 50-60 meters. The chalcopyrite deposits of the Karabash region are quite uniform in content and are made up of pyrite, chalcopyrite, tennantite, sphalerite, and sometimes galenite. At the upper levels, the pyrites are sometimes enriched with covellite. A characteristic of these beds is the increase in zinc content with increase in depth. Among the vein minerals are barite, quartz, calcite, gypsum, sericite, and chlorite. The "Kuznechikh" beds consist of a barytic vein, thickly impregnated with sulfide zinc, iron, copper, and lead, which lies in quartz-sericitic and quartz-chloritic shale. The ore minerals include pyrite, sphalerite, bornite, covellite, and galenite.

The Blyavinskiy ore-mining region contains the Blyavinskoye chalcopyrite deposit, located in Orskiy Rayon, Chkalov Oblast. The primary minerals are pyrite, marcasite, chalcopyrite, and, less frequently, sphalerite, galenite, and tennantite. The iron hat extends to a depth of 50 meters and is rich in sulfates, especially jarosite. Covellite, chalcosine, and chalcanthite are present in the zone of concentration.

The Tanalyk-Baymak mining region includes a group of gold and chalcopyrite deposits extending along both sides of the Iredyk range in the Bashkir ASSR. The Irendyk range is formed of tuff and porphyrites. The many copper deposits of the region stretch in three meridional lines. The Bakr-Uzyak and Sibay deposits belong to the eastern group, the Tubinskoye and Yulalinskoye deposits to the central group, and the Yulunskoye deposit to the western group. The largest deposits of the region are at Sibay and Buribay. All of them appear on the surface as iron hats or limonited quartz veins, rich in gold. Below these are the sulfide ores, enriched in the upper zones by secondary copper compounds. Zinc and barite are present in all the ores.

Copper sandstones occupy a large territory in the southern Urals. The following three regions are differentiated, according to their mineral concentration: Perm, Kazansko-Vyatka, and Orenburg-Ufa.

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Separate sections, rich in copper, have been exploited since the 17th century. According to data in the archives, the copper content in individual ore pockets ranged from 0.5 to 7.5 percent. In some cases, a copper content of 14 to 25 percent has been noted. The average copper content in melted ores was 2.1 to 3.1 percent. The depth of the beds varies from 2 to 72 meters, with an average of 18 meters. The thickness of individual beds varies from 0.05 to 0.9 meter, with the average 0.2 meter. The thickness of the beds increases with depth. The beds are in the form of irregular lentils, pancake-like formations, or branching columns. The average area of an ore bed is 2,500 square meters.

From the second half of the 17th century until 1915, 10,000 small mines, working separate ore pockets, mined 225,000 tons of copper.

Kazakhstan Deposits

Two types of copper mineralization are distinguished in Kazakhstan: copper sands, which include the Dzhezkazgan group of deposits, and copper-porphyritic deposits, represented by Kounrad.

The Dzhezkazgan copper ore deposits are located in Central Kazakhstan. This deposit is unique and of world-wide significance in known reserves and concentrations of copper.

In structure the Dzhezkazgan deposit is composed of a type of epigenetic impregnated copper ores in gray sandstones. The width of mineralization extends 650 meters. The ore-bearing sandstones consist of 30-65 percent feldspar rock, 7-20 percent quartz, 4-10 percent quartzite, and as much as 6 percent porphyrite.

The composition of the ore minerals of Dzhezkazgan is simple. The main primary sulfides are chalcopyrite and bornite, while the less important include tetrahedrite and pyrite. The secondary sulfides are chalcocite and covellite.

Pyrite is found in the form of lean phenocrysts. Bornite and chalcopyrite are found, sometimes in the form of compact ores, but more frequently in the form of comparatively rich phenocryst, gradually changing into lean, scattered ores.

The sulfide ores are sometimes quite near the surface, but bornite and chalcopyrite are more frequently replaced, to a depth of 25 meters, by oxidized ores, mainly malachite. In addition to malachite, the oxidized ores include cuprite, azurite, chrysocolla, brochantite, native copper, and silver. Oxidized ores constitute about 15 percent of the entire reserves.

The sulfide ores are hard, massive, and somewhat laminated. The oxidized ores are soft and sometimes porous and crumbling.

The central portions of individual lentils are remarkable for their increased copper content. Toward the periphery the copper content gradually diminishes, as phenocrysts become predominant.

The Kounrad copper deposit is situated in Central Kazakhstan, 20 kilometers north of Lake Balkhash. It is of the copper-porphyritic type. The ores are a fine-grained mass of secondary quartzites with impregnation, in the primary zone, of pyrite, chalcopyrite, and, rarely, molybdenite. The pyritic grains are often covered with a coating of chalcopyrite. The tennantite here is associated with pyrite and chalcopyrite. The presence of chalcosine, lesser quantities of bornite, and covellite is characteristic of the zone of secondary concentration.

The oxidized ores of the upper zone of the deposits contain malachite, azurite, occasionally blue verditer and chrysocolla, and sometimes traces of cuprite. Among the nonmetallic ores, secondary quartz, sericite, kaolin, limonite, and hematite should be mentioned.

Uzbekistan Deposits

The Almalyk copper ore deposits are situated 15 kilometers from the city of Tashkent in the northern foothills of the Kurminsk range, and at a distance of 5 kilometers from the Angren River. Almalyk is a part of the Karamazar mining region. In total copper reserves, the Almalyk deposits are among the largest in the USSR, occupying second place after Dzhezkazgan. The Almalyk ores are of four types: oxidized, mixed, chalcosine, and primary. The different types of ores do not occur in clearly defined zones either vertically or horizontally. Frequently, streaks of oxidized ores are found in a stratum of mixed ores, while mixed ores are often wedged into chalcosine strata. The proportion of oxidized and mixed ores of all categories is about 15 percent of the total reserves.

The copper minerals found in the oxidized and mixed ores are malachite, chrysocolla, ehlite, and chalcosine. Iron is present in the form of limonite. In the chalcosine and primary ores, copper is represented by chalcopyrite and chalcosine. The enclosing rocks are quartz, sericite, sericitic feldspar, and, partially, mica and chlorites. The ores contain, on the average, 65-80 percent silica, 7 to 14 percent alumina, 8-11 percent ferric oxides, 1.5 percent calcium oxide, and 1 percent magnesium oxide. Concentration of the ore is rather difficult because of the very fine impregnation of the copper minerals and the presence of phosphate copper.

Transcaucasus Deposits

The two regions in the Transcaucasus where copper ores are mined on a commercial scale are Alaverdi and Zangezursko-Merginskiy.

The Transcaucasus copper deposits are divided by form and stratification into veiny deposits -- Katar-Kavartskoye deposit of the Zangezur region, block deposits -- the Alaverdi group, of which the largest are Alaverdi and Shamlug, and impregnated deposits -- Agarak and Pirdoudan.

The ores of the majority of the Transcaucasian deposits consist of a mixture of copper and sulfuric pyrites in various proportions. Small quantities of zinc blende and lead glance are mixed in with the pyrites. In some of the deposits, the ore, because of the zinc and lead content, is polymetallic rather than cuprous. Magnetic pyrite, magnetite, and iron glance are found in some deposits. Variegated copper ore and tennantite are found in insignificant quantities. Molybdenite and arsenopyrite are found in many of the deposits. The nonmetallic minerals are quartz, secondary mica minerals, calcite, and, in some of the deposits, barite and gypsum.

The ores of the Alaverdi region are a mixture of sulfur and copper pyrites. The deposit also contains blocks consisting almost entirely of sulfur pyrite.

The ores of the Leninskaya group of deposits of the Katar-Kavartskiy region consist of copper and sulfur pyrites, with the former predominating. The ores of the Shaumyanovskaya group of vein deposits of the Katar region are polymetallic, with zinc blende predominating.

The Agarak and Pirdoudan deposits consist of a lean impregnation of copper and sulfur pyrites in quartzitic granodiorite. Molybdenite is found here and there.

DEPOSITS OF THE NICKEL INDUSTRY

In the USSR, nickel is obtained from two types of ore: oxidized ores and sulfide ores. The two types of ores are found in deposits which are separated geographically. Oxidized ores are found primarily in the Urals, while the sulfide ores are found in the region of the Arctic Circle.

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Ural Deposits

The first nickel ores to be utilized in the USSR were oxidized ores, deposits of which are in the Central and Southern Urals.

The ores of the Central Urals (Ufaley, Rezh, and other regions) are deposited at the contacts of serpentine rocks and limestone in karstic cavities. These ores are comparatively rich in nickel, although they are characterized by an extraordinary nonuniformity in metal and dead rock content. The average amounts of the ore components are: 23-25 percent H_2O; 38-51 percent SiO_2; 15-25 percent Fe_2O_3; 9-18 percent MgO. The ore is soft, earthy rock which contains quartzitic inclusions varying in size from a small pebble to a large boulder one meter in diameter.

The ores of the Southern Urals lie in the form of layers in serpentine rocks. These ores are characterized by a greater uniformity in content, but contain less nickel. They are deposited in large blocks in the form of a clayey (near the surface), occasionally sandy or talc, mass. Among the large deposits of oxidized nickel ores in the Southern Urals are the Aydarbakskoye, Akkermanovskoye, Batamshinskoye, and other deposits. The average content of an air-dried sample of South Ural nickel ore is as follows: 12-28 percent Fe_2O_3; 8-23 percent MgO; 1.8-2.9 percent CaO; 23-35 percent H_2O; 38-47 percent SiO_2. The greater the amount of ferric oxide in the ore, the lesser the amount of magnesium oxide. There is an almost complete absence of copper in the oxidized nickel ores (0.002 percent Cu).

Nickel in the oxidized ores is found in the form of complex silicates. Most frequently the metal is found in an isomorphic compound of silicates of nickel and magnesium: $(Ni, Mg)O \cdot SiO_2 \cdot nH_2O$. The presence of nickel in more complex silicates is also possible: $2(Al_2O_3 . SiO_2)$, $3(xMgO . SiO_2 . yNiO . SiO_2)$, $10H_2O$. Some mineralogists have suggested that nickel is in the ore in the form of an oxide which forms a colloidal solution with the silicates.

Iron in the oxidized ores is found primarily in the form of limonite $\eta Fe_2O_3 \cdot mH_2O$. The iron content of the ore decreases with depth. The nickel content is independent of the amount of iron in the ore.

Magnesium oxide is present in the ore in the form of talc $3MgO \cdot 4SiO_2 \cdot H_2O$. The talc content of the ore, and consequently its infusibility, increases with depth.

Aluminum oxide is present in the ore in the form of clay $Al_2O_3 \cdot 2SiO_2 \cdot 2H_2O$. The upper strata of the deposits are more clayey than the lower.

Silicic acid enters into the composition of the silicates but it is found in a free state (in the sandy ores). The small and large stones and the boulders consist chiefly of quartz.

Cobalt is almost always present in nickel ores. There seems to be no regular connection between the cobalt and nickel content in the ore. There are sections of the deposits enriched by cobalt, but with a low nickel content, and vice versa. A certain association of cobalt with manganese has been observed. The large quantity of pyrolusite present in the ore is usually associated with a high cobalt content.

Deposits of the Artic Region

The three nickel-bearing regions in the Arctic are Monche-Tundra, Pechenga, and Noril'sk. Monche-Tundra and Pechenga (Petsamo) are on the Kola Peninsula, and Noril'sk is at the mouth of the Yenisey.

The Monche-Tundra deposits contain nickel-copper sulfide ores associated with ultrabasic rocks. The chief ore minerals in the deposits of this region are pyrrhotine, chalcopyrite, pentlandite, and magnetite. Cubanite, sphalerite, pyrite, and ilmenite are sometimes present in the ore. The pyrrhotine is of the greatest significance.

The ores of Monche-Tundra can be divided into four categories, according to their composition: nonfeldspathic-olivine, feldspathic-olivine, feldspathic-nonolivine, and compact sulfides.

The ores can be divided as follows, according to their magnesium content: high magnesian, 31-32 percent MgO; medium magnesian, 24-25 percent MgO; low magnesian, not more than 14 percent MgO.

The more alumina and calcium oxide present in the ore, the lower the magnesium oxide content.

There is more nickel than copper in all the ores. The ratio of nickel to copper varies from 1:1 to 5:1; the ratio of nickel to cobalt varies from 24:1 to 34:1. Cobalt is found in the form of an isomorphic admixture in nickel in ferronickel and nickel sulfides.

The deposits richest in metal content are the veiny deposits of compact sulfides found at Nittis-Kumuzh'ye. The peculiar characteristic of these veins is the almost complete absence of minerals of dead rock. Iron, nickel, copper, cobalt, and sulfur make up 91.5 percent of the veins. The remaining 8.5 percent includes SiO_2, MgO, and Al_2O_3 found in the silicates which are present in the form of xenolites in the surrounding rock.

The Sopchuayvench deposit is of the phenocryst type. There are four types of ore in these deposits, based on the character of the surrounding rock: olivenites, olivine pyroxenites and peridots, coarse-grained pyroxenites, and medium-grained pyroxenites. The chief ore-producing minerals are pyrrhotine, pentlandite, and chalcopyrite. The phenocrysts are from 0.5 to 1.0 millimeter in size. The quantity of sulfides in relation to the enclosing rock varies from 1 to 10 percent.

The deposits of the Noril'sk mining region contain copper-nickel ores. The ratio of nickel to copper is less than one, in contrast with Monche-Tundra, where nickel always predominates over copper. The Noril'sk ores are divided into three basic types: (1) impregnated ores in gabbro-diabases; (2) contact ores, which, depending on the enclosing rock, are divided into aphalitic, diabase, and sedimentary; and (3) sulfide vein ores.

The mineralogical composition of the ores is characterized by the presence of pyrrhotine, chalcopyrite, pentlandite, and small quantities of pyrite and magnetite.

The Noril'sk deposits are divided into three areas according to the degree the area has been prospected and the industrial reserves in the area. These areas are "Ugol'nyy Ruchey," "Rudnaya Gora," and "Medvezhiy Ruchey."

In the "Ugol'nyy Ruchey" deposits, the industrial concentrations of nickel are associated with an intrusion of gabbro-diabases. The impregnated ores in the gabbro-diabases form a sheet-like deposit. The "Rudnaya Gora" deposits are of the contact type. The "Medvezhiy Ruchey" deposits are adapted to ataxitic varieties of gabbro-diabases. In addition to the impregnated mineralization in gabbro-diabases and contact rocks, compact sulfide bodies in the form of lentils and veins have developed in these deposits.

DISTRIBUTION OF LEAD PLANTS

The four lead plants in operation in the USSR are the Tetyukhe Plant in Primorskiy Kray in the Far East, the Leninogorsk Plant in the Altay Mountains, the Chimkent Plant in southern Kazakhstan, and the Dzaudzhikau Plant in the North Osetian ASSR.

The distribution of lead-smelting plants in the USSR is based on the location of large polymetallic ore deposits. The Tetyukhe Plant refines the lead concentrates and oxide ores of the Primorskiy basin (Far East). The Tetyukhe Plant is the only one in the Soviet Union that practices forge-smelting of lead.

The Leninogorsk Lead Plant treats concentrates and ores of the large ore-bearing Altay basin. It also treats the tailings of the zinc plant. The fact that the ores of the Altay region are polymetallic determines the technical complexity of lead production at the Leninogorsk Plant.

The Chimkent Lead Plant is designed to treat concentrates obtained from the polymetallic ores of the numerous deposits of Central Asia.

The Dzaudzhikau Lead Plant treats the lead concentrates of the Sadon mining region and the lead-bearing tailings of the zinc plant.

The lead plants of the USSR have a full production cycle. The final product of the plants is highest-quality refined lead.

DISTRIBUTION OF ZINC PLANTS

Three factors are taken into consideration in the distribution of zinc plants. These factors are: proximity of deposits of zinc or polymetallic ores; possibility of on-the-spot utilization of metallic zinc and sulfuric acid (for each ton of zinc 2 tons of monohydrate of sulfuric acid are obtained); and the presence of cheap energy or fuel (4 tons of equivalent fuel or 4,000 kilowatt-hours of electricity are required for each ton of zinc).

The Ust'-Kamenogorsk Electrolytic Zinc Plant is located in the Altay Mountains (Kazakhstan) on the bank of the Irtysh River. Located in the Altay polymetallic ore region, it is the principal center for the production of electrolytic zinc, sulfuric acid, cadmium, and a number of chemical products.

The Dzaudzhikau zinc-distillation and zinc-electrolytic plants, located in the North Osetian ASSR (North Caucasus), were destroyed in the German invasion. The old, rebuilt zinc-distillation plant and the large new electrolytic-zinc plant that had been built alongside it, treated the zinc concentrates obtained by concentration of ores of the Sadon region (North Osetian ASSR). The plants constituted a complete chemical-metallurgical combine with a number of by-products, including sulfuric acid, blue vitriol, cadmium, and others. The presence of a Welsh installation [vel'tsustanovka] for treating tailings of zinc production, as well as the presence of a near-by lead plant, were instrumental in obtaining high indexes of metal recovery.

The Chelyabinsk Electrolytic Zinc Plant, located in the city of Chelyabinsk (Southern Urals), is designed for the treatment of zinc concentrates obtained by flotation of the copper-zinc ores of the Urals.

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The Konstantinovka Zinc-Distillation Plant (Donbass) was designed for the treatment of Ural and Tetyukhe concentrates. The presence of high-quality clays and fuel and the demand of local industries for sulfuric acid and zinc were factors in building the plant in this region. The plant was destroyed by the Germans.

The Belovo Zinc-Distillation Plant in the Kuzbass (Western Siberia) treats zinc concentrates that are obtained from the Salair Concentration Plant.

DISTRIBUTION OF COPPER PLANTS

Copper production in the USSR is concentrated in the two most important ore-bearing regions of the country, the Urals and Central Kazakhstan.

Copper Smelting Plants

There are six copper-smelting plants in operation in the Urals: Krasnoural'sk, Sredneural'sk, Kirovograd, Karabash, Mednogorsk, and Tanalyk-Baymak. In Central Kazakhstan, the Balkhash and Karsakpay plants are in operation and a new plant is under construction at Dzhezkazgan. In the Altay region, the Irtysh Copper Plant operates in conjunction with the lead plant. The Alaverdi Plant is located in Armenia.

The Ural copper plants are located near deposits of copper-pyrite ores. The newly constructed Krasnoural'sk and Sredneural'sk copper plants include the following operations: flotation of the ores, smelting of concentrates in reverberatory furnaces, and subsequent Bessemer conversion of the mattes. The old, rebuilt copper plants of Kirovograd and Karabash, in addition to their concentration plants and reverberatory furnaces, have also retained the water-jacket process of smelting lump ores. The newly constructed copper plant in Mednogorsk (Orsk) smelts copper-pyrite ores in water-jacket furnaces, obtaining elementary sulfur as a by-product of copper mattes. In Bashkiriya, a small plant at Tanalyk-Baymak smelts copper-pyrite ores in water-jacket furnaces. The discovery of large reserves of copper at Sibay and Buribay, near the Tanalyk-Baymak plant, poses the question of radically reconstructing this plant.

The copper ores of the Central Kazakhstan deposits are of an entirely different type. While the Ural ores are basically compact copper-pyrite deposits, the Kazakhstan ores are impregnated copper-porphyritic deposits and sandstones.

The copper-smelting base in the extensive Dzhezkazgan region is the small copper plant at Karsakpay. A copper-refining plant is in construction on the Kara-kingir River, near Dzhezkazgan. This plant's operation will include flotation of the ores and smelting of concentrates in a reverberatory furnace.

The large copper plant on the shore of Lake Balkhash treats copper concentrates obtained by flotation concentration of the ores of the Kounrad deposits.

The Irtysh Copper Plant, located in the Altay region, treats the copper ores of the Altay ore basin. This plant is equipped with sintering equipment and water-jacket furnaces.

In the Caucasus, a copper plant at Alaverdi in Armenia treats local and Zangezur concentrates in reverberatory furnaces.

Copper Refining Plants

These plants are centralized and are located in the Urals and in Moscow. The largest is the newly constructed electrolytic copper plant at Pyshma, Sverdlovsk Oblast. The plant at Kyshtym, Chelyabinsk Oblast, has been entirely modernized. The electrolytic copper plant at Moscow refines both primary and secondary copper.

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DISTRIBUTION OF NICKEL PLANTS

The nickel industry of the USSR is based on the oxide nickel ores of the Urals and the sulfide copper-nickel ores of Monche-Tundra (Karelia), Noril'sk (mouth of the Yenisey), and Pechenga (Petsamo).

During the period of the Stalin Five-Year Plans, the Rezh, Ufaley, and Orsk nickel plants were constructed in the Urals. The largest plant is the one at Orsk.

On the basis of the ores at Monche-Tundra, a copper-nickel plant has been built at Monchegorsk. In the North there is a plant at Petsamo.

A copper-nickel plant was constructed in the Far North. This plant utilizes Noril'sk ores.

Content of Charge in Smelting Oxide Nickel Ores (% of ore weight)

Plant	Nickel Ore	Limestone	Gypsum	Pyrite	Turnover Slag	Coke Consumption
Orsk						
From-to	100 sinter	29.7-40.8	10.75-16.85		8.15 33.0	--
Average	100 sinter	33.72			31.7	35.0
Ufaley	100	32.36	7.7-5.8		--	28-32
Rezh	100	44.3	6.7		--	31.4

Ore Analysis for Charge in Shaft-Furnace Smelting of Oxide Nickel Ores (%)

Plant	Ni	SiO_2	Fe_2O_3	CaO	MgO	Al_2 3
Orsk						
Ore	--	42.64	23.30	2.5	12.5	3.8
Sinter	--	46.07	29.00	--	14.09	--
Rezh						
Ore	--	40-50	15-25	1-2	1-5	15-20

Analysis of First Mattes of Shaft-Furnace Smelting of Oxide Nickel Ores (%)

Plant	Ni- Co	Fe	Cu	S
Orsk*	15.74	55.96	0.08	22.55
Ufaley	10.4-22.7	54.4-65.0	0.03-0.12	17.22-23.43
Rezh	16.59	55.12	0.34	23.86

*In addition, the matte contains 2.5 percent SiO_2; 0.47 percent CaO; 0.42 percent MgO.

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Analysis of Copper-Nickel Ores and Concentrates (%)

Deposit	Ni	Cu	Fe	S	SiO_2	Al_2O_3	CaO	MgO
Kumuzh'ya Naroka	--	--	51.57	28.0	1.64	0.19	--	1.09
Nittis, ore								
From	--	--	55.20	37.84				
To	--	--	54.0	36.40	--	--	--	--
Nittis, concentrates								
From	--	--	10.55	3.90	42.48	5.29	2.43	19.71
To	--	--	--	4.15	45.40	6.87	2.61	27.17
Noril'sk, concentrates								
"Ugol'nyy ruchey"								
From	--	--	17.76	9.47	17.15	1.52	6.65	1.10
To	--	--	28.40	21.42	30.00	5.57	11.34	6.57
"Gora rudnaya"	--	--	29.30	22.44	17.95	5.57	4.15	1.85
"Noril'sk II"	--	--	25.27	18.51	20.52	5.98	9.24	2.06

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